Evaluation of Sorbent Injection for Mercury Control

Quarterly Technical Report
Reporting Period: July 1, 2005–September 30, 2005

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ABSTRACT

The power industry in the U.S. is faced with meeting new regulations to reduce the emissions of mercury compounds from coal-fired plants. These regulations are directed at the existing fleet of nearly 1,100 boilers. These plants are relatively old with an average age of over 40 years. Although most of these units are capable of operating for many additional years, there is a desire to minimize large capital expenditures because of the reduced (and unknown) remaining life of the plant to amortize the project. Injecting a sorbent such as powdered activated carbon into the flue gas represents one of the simplest and most mature approaches to controlling mercury emissions from coal-fired boilers.

The overall objective of the test program described in this quarterly report is to evaluate the capabilities of activated carbon injection at five plants with configurations that together represent 78% of the existing coal-fired generation plants. This technology was successfully evaluated in NETL's Phase I tests at scales up to 150 MW, on plants burning subbituminous and bituminous coals and with ESPs and fabric filters. The tests also identified issues that still need to be addressed, such as evaluating performance on other configurations, optimizing sorbent usage (costs), and gathering longer-term operating data to address concerns about the impact of activated carbon on plant equipment and operations. The four sites identified for testing are Sunflower Electric's Holcomb Station, AmerenUE's Meramec Station, AEP's Conesville Station, and Detroit Edison's Monroe Power Plant. In addition to tests identified for the four main sites, baseline and parametric testing at Missouri Basin Power Project's Laramie River Station Unit 3 was made possible through additional cost-share participation targeted by team members specifically for tests at Holcomb or a similar plant.

This is the eighth quarterly report for this project. Testing at Monroe Station was completed during this reporting period. Preliminary results from long-term testing are included in this report. Planning information for the final test site, Conesville, is also included. In general, quarterly reports are used to provide project overviews, project status, and technology transfer information. Topical reports will be prepared for each test site and these will include detailed technical information. The topical report for evaluations conducted at Meramec Station was submitted to DOE during this reporting period.

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INTRODUCTION

The overall objective of this test program is to evaluate the capabilities of activated carbon injection at five plants with configurations that together represent 78% of the existing coal-fired generation plants. Activated carbon injection was successfully evaluated in NETL's Phase I tests at scales up to 150 MW on plants burning subbituminous and bituminous coals and with ESPs and fabric filters. The tests also identified issues that still need to be addressed, such as evaluating performance on other configurations, optimizing sorbent usage (costs), and gathering longer-term operating data to address concerns about the impact of activated carbon on plant equipment and operations. A summary of the key descriptive parameters for the host sites can be found in Table 1. Laramie River Station was added as the fifth site in the program during 4Q04.

The technical approach that is being followed during this program allows the team to: 1) effectively evaluate activated carbon and other viable sorbents on a variety of coals and plant configurations, and 2) perform long-term testing at the optimum condition for at least one month. These technical objectives will be accomplished by following a series of technical tasks:

Task 1. Design and Fabrication of Sorbent Injection System

Task 2. Site-Specific Activities including Field-Testing

Task 3. Technology Transfer

Task 4. Program Management and Reporting

Tasks 1, 3, and 4 are intended to support the overall direction, implementation, technology transfer, and management of the program. Task 2 will be repeated for each test site with subtasks designed to address the specific configurations, needs, and challenges of that site. Task 2 is the heart of the program and contains subtasks to address each important component of the testing. A summary of the Field-Testing (Task 2) subtasks is presented in Table 3.

Table 1. Host Site Key Descriptive Information.

	Holcomb	Meramec	Laramie River	Monroe	Conesville
Test Period	3/04–8/04	8/04–11/04	2/05–3/05	3/05–6/05	3/06–5/06
Unit	1	2	3	4	5 or 6
Size (MW)	360	140	550	785	400
Coal	PRB	PRB	PRB	PRB/Bit blend	Bituminous
Particulate Control	Joy Western Fabric Filter	American Air Filter ESP	ESP	ESP	Research-Cottrell ESP
SCA (ft^2/kacfm)	NA	320	599	258	301
Sulfur Control	Spray Dryer Niro Joy Western	Compliance Coal	Spray Dryer	Compliance Coal	Wet Lime FGD
Ash Reuse	Disposal	Sold for concrete	Disposal	Disposal	FGD Sludge Stabilization
Test Portion (MWe)	180 and 360	70	140	196	400
Typical Inlet Mercury ($\mu g/dNm^3$)	10–12	10–12	10–12	8–10	15–20
Typical Native Mercury Removal	0–13%	15–30%	<20%	10–30%	50%

A detailed topical report will be prepared for tests conducted at each test site. Quarterly reports will be used to provide project overviews, status, and technology transfer information.

EXECUTIVE SUMMARY

This five-site project is part of an overall program funded by the Department of Energy's National Energy Technology Laboratory (NETL) and industry partners to obtain the necessary information to assess the feasibility and costs of controlling mercury from coal-fired utility plants. Host sites that will be tested as part of this program are shown in Tables 1 and 2. These host sites reflect a combination of coals and existing air pollution control configurations representing 78% of existing coal-fired generating plants and, potentially, a significant portion of new plants. These host sites will allow documentation of sorbent performance on the following configurations:

Table 2. Host Sites Participating in the Sorbent Injection Demonstration Project.

	Coal/Options	APC	Capacity MW/ Test Portion	Current Hg Removal (%)
Sunflower Electric's **Holcomb Station**	PRB and Blend	SDA – Fabric Filter	360/180 and 360/360	<15
AmerenUE's **Meramec Station**	PRB	ESP	140/70	15–30
American Electric Power's (AEP) **Conesville Station**	Bituminous Blend	ESP + Wet FGD	400/400	50
Detroit Edison's **Monroe Power Plant**	PRB/Bit Blend	SCR + ESP	785/196	10–30
Missouri Basin Power Project's **Laramie River Station**	PRB	SDA – ESP	550/140	<20

During the eighth reporting period, July through September 2005, progress on the project was made in the following areas:

AmerenUE, Meramec

- Completed Meramec topical report

MBPP, Laramie River Station

- Completed Laramie River draft topical report

Detroit Edison, Monroe

- Complete long-term testing
- Conduct coal and byproduct analyses
- Preparing draft topical report

AEP, Conesville

- REI conducting flow modeling of Conesville ESP inlet
- Prepare for sorbent screening tests in November

EXPERIMENTAL

The overall objective of this test program is to evaluate the capabilities of activated carbon injection at five plants with configurations that together represent 78% of the existing coal-fired generation plants. ADA-ES and the project team will evaluate activated carbon and other viable sorbents on a variety of coals and plant configurations, and perform long-term testing at the optimum condition for up to six weeks. The technical approach is outlined in a series of four technical tasks.

Task 1. Design and Fabrication of Sorbent Injection System

ADA-ES, the primary test contractor, will provide the majority of the process equipment that will travel from site to site. This equipment is sized and designed to cover the expected range of plant sizes (70–800 MW) and flue gas conditions, and has the flexibility for both baghouse and ESP applications.

Task 2. Site-Specific Activities Including Field-Testing

This task has seven subtasks. All subtasks will be repeated at each host site, except long-term testing which was not conducted at Laramie River Station. A summary of these subtasks is presented in Table 3. The five sites identified for testing are Sunflower Electric's Holcomb Station, AmerenUE's Meramec Station, Missouri Basin Power Project's Laramie River Station, Detroit Edison's Monroe Power Plant, and AEP's Conesville Station. Testing at Laramie River Station was limited to baseline and a short-term series of parametric tests. Testing during this quarter was conducted at Monroe Power Plant. Descriptions of Holcomb, Meramec, Laramie River, and Monroe Station were included in previous quarterly reports. A description of Conesville Station will be included when results are presented.

Table 3. Task 2 Subtasks (to be repeated at each test site).

Subtask	Description
2.1	Host site kickoff meeting, Test Plan, and QA/QC plan
2.2	Design and install site-specific equipment
2.3 2.3.1 2.3.2 2.3.3 2.3.4 2.3.5	Field-tests Sorbent selection Sample and data coordination Baseline tests Parametric tests Long-term tests *(no long-term tests conducted at Laramie River)*
2.4	Data analysis
2.5	Sample evaluation
2.6	Economic analysis
2.7	Site (topical) report

Subtask 2.1. Host Site Planning and Coordination

Efforts within this subtask include planning the site-specific tests with the host site utility, DOE/NETL, and contributing team members. The planning process includes meeting with plant personnel, corporate, and environmental personnel to discuss and agree upon the overall scope of the program, the potential impact on plant equipment and operation, and to gather preliminary information necessary to develop a detailed draft Test Plan and scope of work. Efforts include identifying any permit requirements, developing a quality assurance/quality control plan, finalizing the site-specific scope for each of the team members, and putting subcontracts in place for manual flue gas measurements, including Ontario Hydro mercury measurement services.

Full-scale sorbent injection testing at Conesville has been rescheduled for spring 2006. Progress was made on the ESP inlet flow model by REI. Data from the flow model will be used to design the injection lances. Sorbents were also identified as potential options for mercury control at Conesville and preparations were made for sorbent screening tests.

Subtask 2.2. Design, Fabricate, and Install Equipment

During this subtask, equipment will be identified, designed, fabricated when necessary, and installed at the host site. Some components are site-specific such as the sorbent distribution manifold and sorbent injectors (if possible, these components will be reused at multiple sites). This equipment must be sized, designed, and fabricated for the specific plant arrangements and ductwork configurations. Required site support includes installation of the injection and sampling ports (if not available), installation of required platforms and scaffolding, compressed air, electrical power, wiring plant signals including boiler load to the injection skid and control trailer, and the balance-of-plant engineering. The host utility will be responsible for all permitting and any variance requirements.

Subtask 2.3. Field-Testing

Field-tests are accomplished through a series of five steps. A summary of these steps is presented below.

2.3.1 Sorbent Selection

A key component of the planning process for these evaluations is identifying potential sorbents for testing. To assist in the sorbent selection process, a sorbent screening device (SSD) designed by ADA-ES was used at each site except Laramie River to compare the performance of candidate sorbents. A description of the device used at Holcomb and Meramec was included in the 2Q04 quarterly report. The device used at Monroe and scheduled for use at Conesville will be described when the results are presented.

2.3.2 Sample and Data Coordination

ADA-ES engineers coordinate with plant personnel to retrieve the necessary plant operating data files and determine appropriate samples to collect during baseline, parametric, and long-term testing periods. Samples are collected based upon a Sample and Data Management Plan developed for the sites. An example of the sampling schedule for Meramec and additional descriptions of the sample management protocol were included in the 2Q04 quarterly report.

2.3.3 Baseline Testing

Baseline mercury measurements, consisting of Ontario Hydro testing in conjunction with SCEM measurement, are typically made at each site for at least one week prior to beginning parametric mercury control tests. Baseline SCEM measurements were made at Holcomb, Meramec, Laramie, and Monroe, and are planned for Conesville. During testing at Laramie River Station, sorbent traps were used for comparison tests with the SCEMs. Ontario Hydro sampling and additional tests, such as EPA M26a or EPA M29 measurements, have also been conducted at Holcomb, Meramec, and Monroe, and are planned for Conesville.

2.3.4 Parametric Testing

A series of parametric tests is conducted at each site to determine the optimum operating conditions for several levels of mercury control. Evaluations of NORIT's DARCO® Hg and other sorbents chosen by the test team are typically included. Additional tests, such as coal blending or the introduction of additives onto the coal, may also be included.

2.3.5 Long-Term Testing

Thirty-day "long-term" testing has been completed at Holcomb and Meramec, was conducted during this reporting period at Monroe, and is planned for Conesville. The sorbents used during the long-term test period are chosen by the test team based upon performance during parametric testing and a review of the material costs and availability. The goal of the 30-day test phase is to obtain operational data on mercury removal efficiency, the effects on the particulate control device, effects on byproducts and impacts to the balance-of-plant equipment, to prove viability of the process, and determine the economics. During these tests, Ontario Hydro measurements are conducted at the inlet and outlet of the particulate control device at least once.

Subtask 2.4. Data Analysis

Data collection and analysis for this program are designed to measure the effect of sorbent injection on mercury control and the impact on the existing pollution control equipment. The mercury levels and plant operation are characterized without sorbent injection, during coal blending or coal additive testing, and with various injection rates and possible combustion modifications, as defined by the final Site Test Plan.

Subtask 2.5. Coal and Byproduct Evaluation

Coal and combustion byproduct samples collected throughout the program are analyzed in this task. During all field test phases, samples of coal and fly ash are collected. At a minimum, ultimate and proximate analyses will be performed and mercury, chlorine, and sulfur levels will be determined in a representative set of the coal samples. Activated carbon injection will result in the fly ash and scrubber materials being mixed with a certain amount of the mercury-containing sorbent. The ash samples will be analyzed at a minimum for mercury and LOI. It is expected that more than 100 samples will be collected at each site. A subset of these samples will be analyzed.

Subtask 2.6. Economic Analysis

After completion of testing and analysis of the data at each plant, the requirements and costs for full-scale permanent commercial implementation of the selected mercury control technology will be determined. The program team will meet with the host utility plant and engineering personnel to develop plant-specific design criteria. Process equipment will be sized and designed based on test results and the plant-specific requirements (reagent storage capacity, plant arrangement, retrofit issues, winterization, controls interface, etc.). A conceptual design document will be developed. Finally, a budget cost estimate will be developed to implement the control technology.

Subtask 2.7. Site (Topical) Report

A site (topical) report will be prepared documenting measurements, test procedures, analyses, and results obtained in Task 2. This report is intended to be a stand-alone document providing a comprehensive review of the testing that will be submitted to the host utility.

Task 3. Technology Transfer

Technology transfer activities include participation in DOE/NETL-sponsored meetings, presentations at conferences, and publication of technical papers. A summary of results from Holcomb, Laramie River, and Meramec was presented at the Air Quality V conference in Washington, DC, in September 2005. A presentation is planned for the POWER-GEN International conference in Las Vegas, Nevada, in December 2005.

Task 4. Program Management and Reporting

The final task provides time for overall program management and time to complete DOE's reporting requirements. This task will also support periodic meetings with DOE to discuss progress and obtain overall direction of the program from the DOE project manager. In addition to the standard financial and technical reports, additional deliverables will include topical reports for each site tested. The Project Schedule and Milestones are presented in Table 4.

Table 4. Project Schedule and Milestones.

Activity	Target Date	Actual Date
Holcomb		
Site Kickoff Meeting	12/16/03	12/16/03
Complete Sorbent Screening Tests	3/4/04	3/2/04
Complete Equipment Installation	5/21/04	4/21/04
Complete Baseline Testing	5/21/04	5/20/04
Initiate Parametric Testing	5/24/04	5/22/04
Complete Parametric Testing	6/11/04	6/11/04
Initiate Long-Term Testing	7/7/04	7/7/04
Complete Team Meeting and Site Tour	7/21/04	7/21/04
Complete Long-Term Test	8/6/04	8/6/04
Complete Economic Analysis	5/31/05	2/28/05
Complete Byproduct Analysis Evaluations	5/31/05	5/31/05
Complete Site (Topical) Report	6/30/05	6/27/05
Meramec		
Site Kickoff Meeting	4/20/04	4/20/04
Complete Pre-Baseline Testing	6/25/04	6/23/04
Complete Sorbent Screening Tests	10/18/04	10/08/04
Complete Equipment Installation	9/5/04	8/23/04
Complete Baseline Testing	9/5/04	8/27/04
Initiate Parametric Testing	9/6/04	8/30/04
Complete Parametric Testing	10/17/04	9/27/04
Complete Team Meeting and Site Tour	12/17/04	10/27/04
Initiate Long-Term Testing	10/18/04	10/14/04
Complete Long-Term Test	12/17/04	11/17/04
Complete Economic Analysis	8/31/05	8/31/05
Complete Byproduct Analysis Evaluations	8/31/05	8/31/05
Complete Site (Topical) Report	9/30/05	9/30/05
Laramie River		
Site Kickoff Meeting	1Q05	1/20/05
Initiate Field-Testing	2Q05	2/21/05
Complete Field-Testing	2Q05	3/8/05
Monroe		
Site Kickoff Meeting	4Q04	1/11/05
Initiate Field-Testing	3Q05	3/22/05
Complete Field-Testing	4Q05	7/1/05
Conesville		
Site Kickoff Meeting	2Q05	3/1/05
Initiate Field-Testing	1Q06	
Complete Field-Testing	1Q06	

There are more than 100 individual team members from 27 organizations participating in this program. Current project co-funding is provided by:

- ADA-ES, Inc.
- ALSTOM
- AmerenUE*
- American Electric Power*
- Arch Coal
- Detroit Edison*
- Dynegy Generation
- EPRI
- Kennecott Coal
- MidAmerican
- NORIT Americas
- Ontario Power Generation and partners
  - EPCOR
  - Babcock & Wilcox
- Peabody Coal
- Southern Company
- Sunflower Electric Power Corporation* and partners
  - Associated Electric Coop
  - City of Sikeston
  - Empire District Electric Company
  - Kansas City Board of Public Utilities (KCKBPU)
  - Kansas City Power and Light
  - Kennecott Coal
  - Missouri Basin Power Project*
  - Nebraska Public Power District
  - PacifiCorp
  - Peabody Coal
  - Southern Minnesota Municipal Power Agency
  - Tri-State Generation & Transmission
  - TransAlta Utilities
  - TransAlta Energy.
  - Westar Energy
  - Western Fuels Association
  - Wisconsin Public Service
- Tennessee Valley Authority

** Indicates host site*

Key members of the test team include:

ADA-ES, Inc.

Project Manager: Sharon Sjostrom

Site Manager: Travis Starns

SCEM Lead: Jerry Amrhein

DOE/NETL

Project Manager: Andrew O'Palko

EPRI

Project Manager: Ramsay Chang

Reaction Engineering International

Coal and byproduct analysis interpretation: Connie Senior

ALSTOM

Scrubber operation and coal additive injection parameters: Leif Lindau

To facilitate information sharing, a project Web site is maintained for the project. The project Web site is password protected and available only to project participants. Information available through the Web site includes all presentations, papers, reports, planning documents, schedules, and other information related to the project.

A schedule showing field-tests planned and completed at each test site is shown in Table 5.

Table 5. Field-Testing Schedule.

	2004				2005					
Site	May	Jul	Sep	Nov	Jan	Mar	May	Jul	Sep	Nov
Holcomb										
Meramec										
Laramie River										
Monroe										
Conesville Spring '06										

RESULTS AND DISCUSSION

Task 1. Design and Fabrication of Sorbent Injection System

Design and fabrication of the sorbent injection system used at Holcomb, Meramec, and Monroe Power Plant was completed during the January–March 2004 reporting period.

Task 2. Site-Specific Activities Including Field-Testing

Baseline and parametric testing with the SCR in-service were completed during the 2Q05 reporting period. Long-term testing at Monroe was completed during this period. Results from baseline and parametric tests with and without the SCR were included in the 2Q05 quarterly report. Results from long-term testing are included under this heading.

Subtask 2.3. Field-Testing

2.3.2 Sample and Data Coordination

Data analysis and coal and byproduct evaluation is ongoing for all sites where field-testing was conducted. Details will be included in the topical reports.

2.3.3 Baseline Testing – Monroe Power Plant

Baseline testing with the SCR bypassed was conducted March 22–24, 2005, and baseline testing with the SCR in-service was conducted May 16–20, 2005. Throughout these periods, mercury measurements were made at the ESP inlet and outlet with mercury analyzers (SCEMs). During two days of each baseline test period, Ontario Hydro mercury measurements were also conducted at the inlet and outlet of the ESP.

2.3.4 Parametric Testing Results

Parametric testing with the SCR bypassed was conducted March 29–31 and April 21, 2005. Testing with the SCR in-service was conducted May 23–26, 2005. During these parametric tests, sorbents were injected at various rates to develop a relationship between sorbent injection rate and mercury removal efficiencies across the ESP.

2.3.5 Long-Term Testing

Long-term testing at Monroe with the SCR in-service was conducted June 1 through July 1, 2005. DARCO® Hg was evaluated during the 30-day continuous injection period. It is likely that sufficient halogens were available from the bituminous coal in the blend at Monroe that bromine-treated DARCO® Hg-LH activated carbon was unnecessary.

A trend graph of mercury emissions and DARCO® Hg injection concentration is presented in Figure 1. No balance-of-plant problems, such as increased opacity or changes in the ESP operation, were noted at Monroe as a result of activated carbon injection.

The average mercury emissions at Monroe for the 30-day long-term test was 0.84 lb/TBtu at an injection concentration of 4.9 lb/MMacf, which represents 78% mercury removal across the system. The target mercury emission for this portion of the test was 1 lb/TBtu.

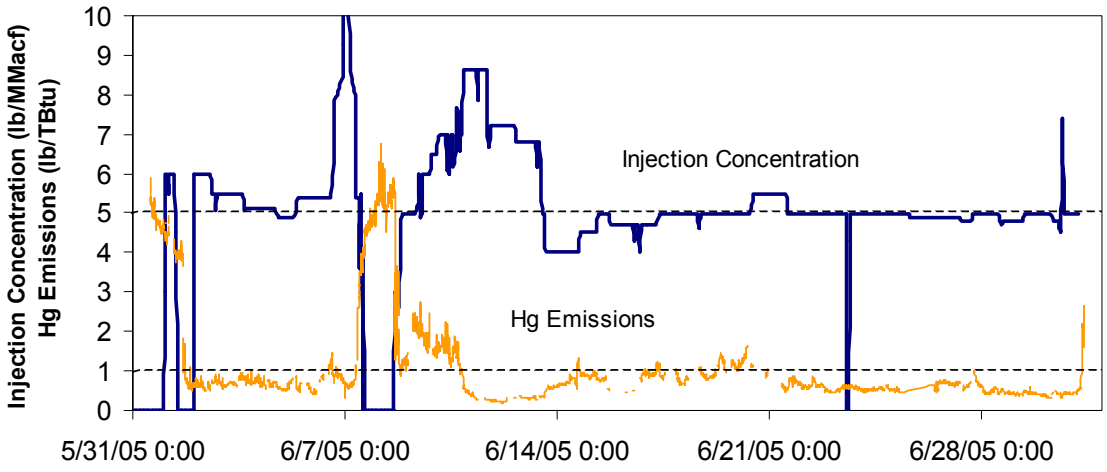

Figure 1. 30-Day DARCO® Hg Injection Test Results from Monroe.

Subtask 2.4. Data Analysis

Data collected from Monroe Power Plant are currently being reviewed.

Subtask 2.5. Coal and Byproduct Evaluation

Hundreds of samples are typically collected from each test site. Most of the ash samples, several coal samples, and at least one of all other sample types will be analyzed for mercury. Additional analyses, including coal ultimate and proximate analyses, and coal and ash chlorine analyses, are being conducted. Results from these tests are being reviewed and will be summarized in the topical report for the site.

CONCLUSIONS

Field-testing has been completed at Holcomb, Meramec, Laramie River, and Monroe Stations. Preliminary results from Monroe long-term tests were reported in this quarterly report. General conclusions and observations from the tests conducted at Monroe Station include:

- **Coal Blending**
  - Baseline removal at Monroe ranged from 7 to 35% (60/40 blend PRB/bituminous). According to data collected during EPA's ICR program, the average mercury removal at sites with ESPs that fire bituminous coal is 46%.
- **Standard Activated Carbon Injection**
  - The average mercury emissions at Monroe for the 30-day long-term test was 0.84 lb/TBtu at an injection concentration of 4.9 lb/MMacf, which represents 78% mercury removal across the system. The target mercury emission for this portion of the test was 1 lb/TBtu.
- **Treated Activated Carbon Injection**
  - DARCO® Hg-LH was not required at Monroe, likely because sufficient halogens were available in the bituminous coal from the blend (60% PRB, 40% bituminous coal).

LIST OF ACRONYMS AND ABBREVIATIONS

ACI	Activated carbon injection
APC	Air pollution control
B&W	Babcock & Wilcox
COC	Chain of Custody
DARCO® Hg	Sorbent manufactured by NORIT Americas. Formerly known as DARCO® FGD
DARCO® Hg-LH	Sorbent manufactured by NORIT Americas. Formerly known as DARCO® FGD-E3
DOE	Department of Energy
ESP	Electrostatic precipitator
FGD	Flue gas desulfurization
ID Fan	Induced draft fan
kacfm	Thousand actual cubic feet per minute
kW	Kilowatt
MW	Megawatt
NETL	National Energy Technology Laboratory
O&M	Operating and Maintenance
PAC	Powdered activated carbon
PC	Pulverized coal
PRB	Powder River Basin
SCA	Specific collection area
SCR	Selective Catalytic Reduction
SCEM	Semi-continuous emission monitor
SDA	Spray dryer absorber
SGLP	Synthetic groundwater leaching procedure
SSD	Sorbent screening device
TCLP	Toxicity characteristic leaching procedure